INCREASING STORAGE CAPACITY IN OLDER COTTON WAREHOUSES

U.S. DEPARTMENT OF AGRICULTURE • AGRICULTURAL MARKETING SERVICE
TRANSPORTATION AND FACILITIES RESEARCH DIVISION AMS-535

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SUMMARY

Storage capacity in cotton warehouse compartments built 25 to 40 years ago can be increased as much as 60 percent if the warehouseman modifies the layout of the compartment and adopts a new method of storing compressed bales in combination with flat bales, as described in this report.

The Agricultural Marketing Service conducts research to increase efficiency in handling and storing cotton to improve cotton's competitive position at home and abroad. Increased efficiency may benefit the consumer by holding down marketing costs for cotton and cotton products.

The number of bales that can be stored is generally limited in older compartments, not only by low-pitched roofs and low sidewalls, but because the main aisle runs the length of the compartment under the highest part of the roof, taking up valuable space that could be used for vertical storage of cotton bales.

In the improved layout, this space is released for storage, and two aisles running the width of the compartment are used as main aisles (only one aisle may be necessary, depending on the size of the compartment). Also, the width of cross aisles is reduced.

If the post spacing is suitable, the greatest increase in storage capacity in the improved layout can be gained by storing compressed bales on head 1 and 2 high toward the sidewalls and flat bales on head 3 high in the highest part of the compartment. Compressed bales are stored with the narrow side of the bale facing the cross aisle. Bale capacity in a compartment 160 feet wide and 270 feet long can be increased from about 4,500 flat bales to some 7,200 flat and compressed bales, or about 60 percent. About one-half of the bales stored are flat bales. Compressed bales stored on head can be broken out of storage with the same equipment used to break out flat bales.

If the warehouseman wishes to store flat bales only, capacity can be increased about 25 percent in the improved layout. In warehouses that store compressed bales in cordwood stacks, the improved layout can increase capacity 7 percent.

In addition to income that may be gained by increasing storage capacity, a warehouseman would have lower unit handling costs with the improved layout because the average distance that bales are transported is reduced.

Modifying a compartment for the improved layout may require relocating doors in the sidewalls and building a 20-foot-wide roadway on one side of the compartment.

Increasing Storage Capacity In Older Cotton Warehouses

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BACKGROUND

Many cotton warehouse and compress facilities located in the Southeast, Midsouth, and in various sections of Texas are from 25 to 40 years old, or even older. These facilities were constructed when bales of cotton were handled manually and by handtrucks, and although warehousemen have since switched to lift-truck handling, the layout of storage compartments has remained unchanged.

Vertical storage space is limited by the building structure (the compartments have low-pitched roofs and low sidewalls) and also by the location and size of the aisles. Flat bales are stored 2 or 3 high on head in those parts of the compartment where the ceiling is high enough, but much of the overhead space is unavailable for storage, because the main aisle runs the length of the compartment, under the highest part of the roof.

Many of these older facilities are in fair condition, and their usefulness could be improved if storage capacity could be increased. Some warehousemen have increased capacity in their facilities by compressing flat bales to standard density as they are received and storing them in cordwood stacks. Stacking bales in cordwood stacks and breaking them out of storage, however, is time consuming and costly. Moreover, bales that are to be exported must be recompressed to high density and the warehouseman must charge the owner for two compressions.

Research to increase the efficiency of handling cotton during the marketing period improves cotton's competitive position in domestic and foreign markets and may benefit the consumer by holding down marketing costs for cotton and cotton products. As part of continuing research by the Agricultural

Marketing Service, a layout, storage patterns, and handling method were developed that provide for maximum use of floor area and vertical storage space and economical handling operations.1/

PRESENT LAYOUT AND STORAGE PATTERN

Most compartments in older warehouses are 10 feet high at the sidewalls and 21 to 24 feet high at the ridge. Wooden posts are generally spaced about 20 feet apart throughout the compartment. These compartments vary in length and width but generally have the same aisle and storage area layout. To illustrate the principles of layout discussed here, a compartment 160 feet wide and 270 feet long is used as an example.

The main aisle, which runs the length of the compartment under the ridge, is 19 to 20 feet wide. Usually two other aisles of the same width run crosswise between the sidewalls. Doorways, 10 by 10 feet, are provided at both ends of each aisle.

Bales are stored in rows two bales wide, running from the sidewalls to the main aisle (fig. 1). The rows are 70 feet long. Double rows are 8 feet wide when flat bales are stored on head, and 10 feet wide when compressed bales are stored in cordwood stacks. Cross aisles between double rows of bales are approximately 5 feet wide (the width necessary when bales were handled on handtrucks).

Storage capacity for flat bales stored on head in this layout amounts to about 4,500 bales. Because of the low sidewalls and low-pitched roof, the first 5 bales from the sidewalls can be stored only 1 high and the next 11 bales in the row can be stacked 2 high (fig. 2). The last 12 bales can be stacked 3 high.

When compressed bales are stored in cordwood stacks in this layout, the first 7 tiers from the sidewalls are stacked 4 bales high, and next 21 tiers 5 high (fig. 2). With 10 rows per section it is possible to store about 8,000 compressed bales in one compartment; with 11 rows, as many as 8,700 can be stored.2/

1/ Warehousemen interested in constructing new facilities are referred to:
Bolt, Charles D., and Bouland, Heber D. Designing a Public Warehouse for Storing Flat Bales of Cotton. U. S. Dept. Agr. Mktg. Res. Rpt. 355, 42 pp. Oct. 1959.
Bouland, Heber D., and Bolt, Charles D. Designing a Public Warehouse for Compressing and Storing Baled Cotton. U. S. Dept. Agr. Mktg. Res. Rpt. 548, 57 pp., illus. Sept. 1962.

2/ The size compartment used here was chosen to illustrate how layout affects storage capacity. An insurance penalty is involved when more than 7,500 bales are stored in one compartment. Compressed bales, however, may be stored in smaller compartments than the one described here, so that the number of bales would not exceed 7,500.

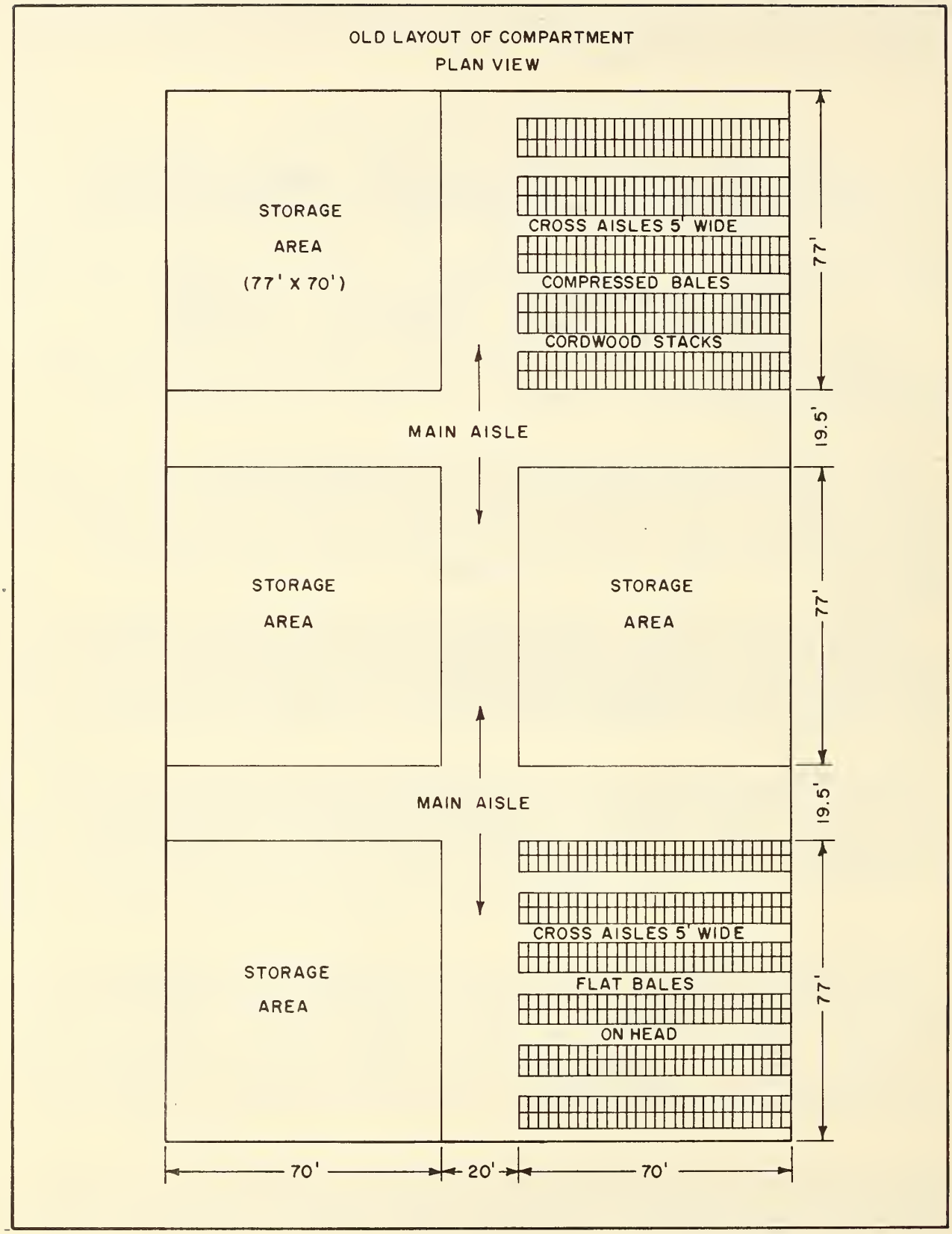
OLD LAYOUT OF COMPARTMENT
PLAN VIEW
STORAGE
AREA
(77' X 70')
CROSS AISLES 5' WIDE
COMPRESSED BALES
CORDWOOD STACKS
77'
MAIN AISLE
19.5'
STORAGE
AREA
STORAGE
AREA
77'
MAIN AISLE
19.5'
STORAGE
AREA
CROSS AISLES 5' WIDE
FLAT BALES
ON HEAD
77'
70'
20'
70'

Figure 1

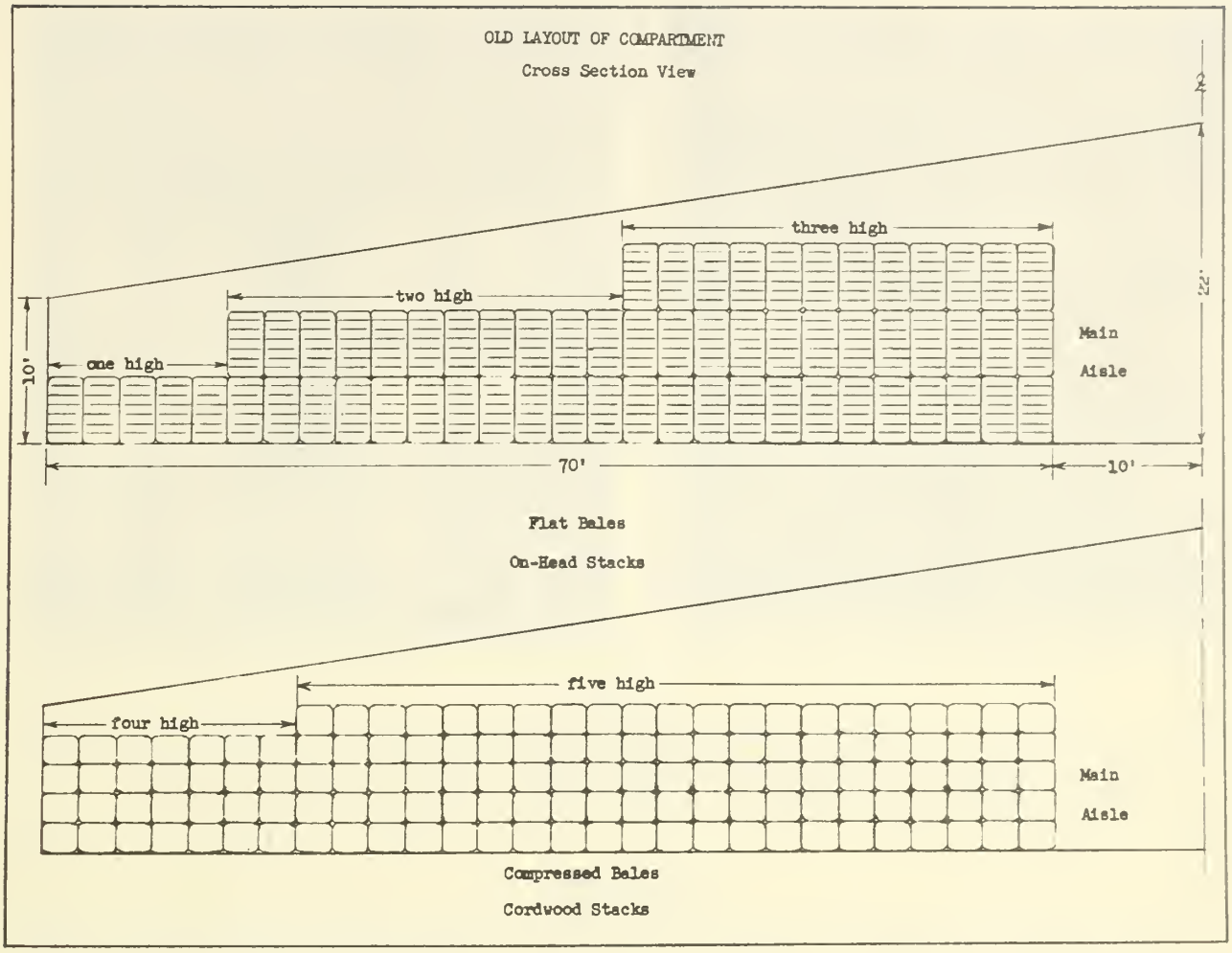

Figure 2

IMPROVED LAYOUT AND STORAGE PATTERN

In the improved layout, the compartment is divided into three storage areas. Two aisles running the width of the compartment are used as main aisles, and storage rows run lengthwise. The area formerly occupied by the main aisle running the length of the compartment is used for storage (fig. 3). Figure 4 shows location and dimensions of storage areas and aisles in the improved layout, and the storage pattern for flat bales. The width of the cross aisles is reduced from 5 to approximately 4 feet. Cross aisles are 5 feet wide when compressed bales are stored in cordwood stacks.

The doors in the end walls should be closed. Doors in the sidewalls, at each end of the two main aisles, should be 12 feet wide and as high as the eaves, to facilitate lift-truck movement.

BN 21802, BN 21803

Figure 3.--In the old layout (left), the main aisle runs the length of the compartment under the highest part of the roof. In the improved layout (right), this space is used to store cotton bales.

Flat Bales

Flat bales are stored in double rows, with 4-foot-wide cross aisles between the double rows. Three rows of bales are stored 1 high on head, 11 rows are stored 2 high on head, and 12 rows, 3 high on head (figs. 4 and 5A). In the two storage areas at the ends of the compartment, the rows are 23 bales long, and in the center section, 47 bales long.

Each end area holds about 1,400 bales, and the center section holds some 2,800 bales, making a total of approximately 5,600 bales. Storage capacity is increased by about 1,100 bales, or about 25 percent over the old layout.

Compressed Bales

Standard density bales are stored in cordwood stacks in double rows, with cross aisles approximately 5 feet wide between the double rows.

There are 21 rows of bales. In 4 rows, bales are stored 4 high in cordwood stacks, and in 17 rows, 5 high (figs. 5B and 6). In each end storage area, the rows are 23 bales long; rows are 47 bales long in the center area.

Each end area holds about 2,300 bales and the center section some 4,700 bales, a possible total of as many as 9,300 bales for the compartment.[3/] Storage capacity is increased about 7 percent.

3/ See footnote 2.

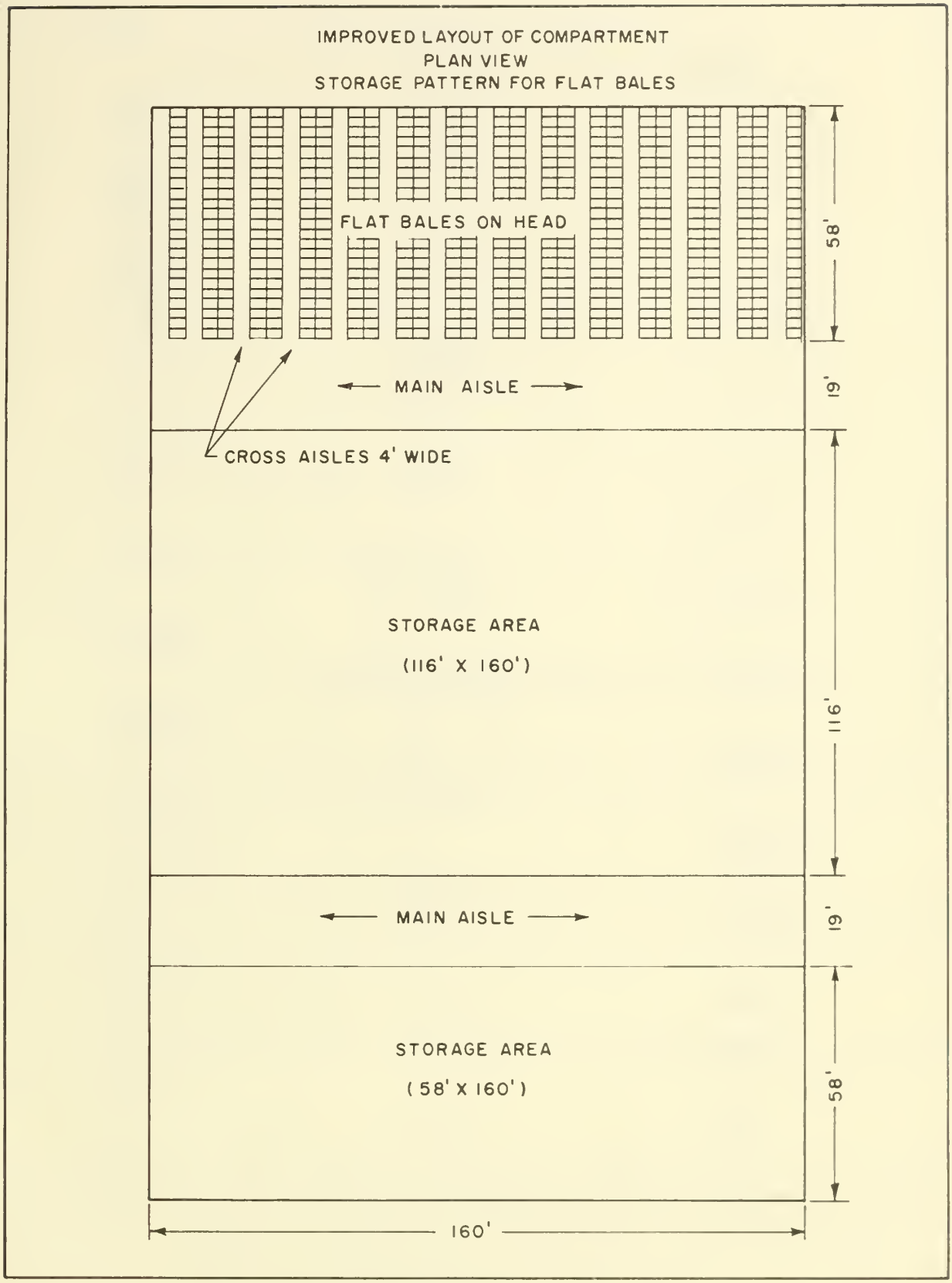
IMPROVED LAYOUT OF COMPARTMENT
PLAN VIEW
STORAGE PATTERN FOR FLAT BALES
FLAT BALES ON HEAD
58'
MAIN AISLE
19'
CROSS AISLES 4' WIDE
STORAGE AREA
(116' X 160')
116'
MAIN AISLE
19'
STORAGE AREA
(58' X 160')
58'
160'

Figure 4

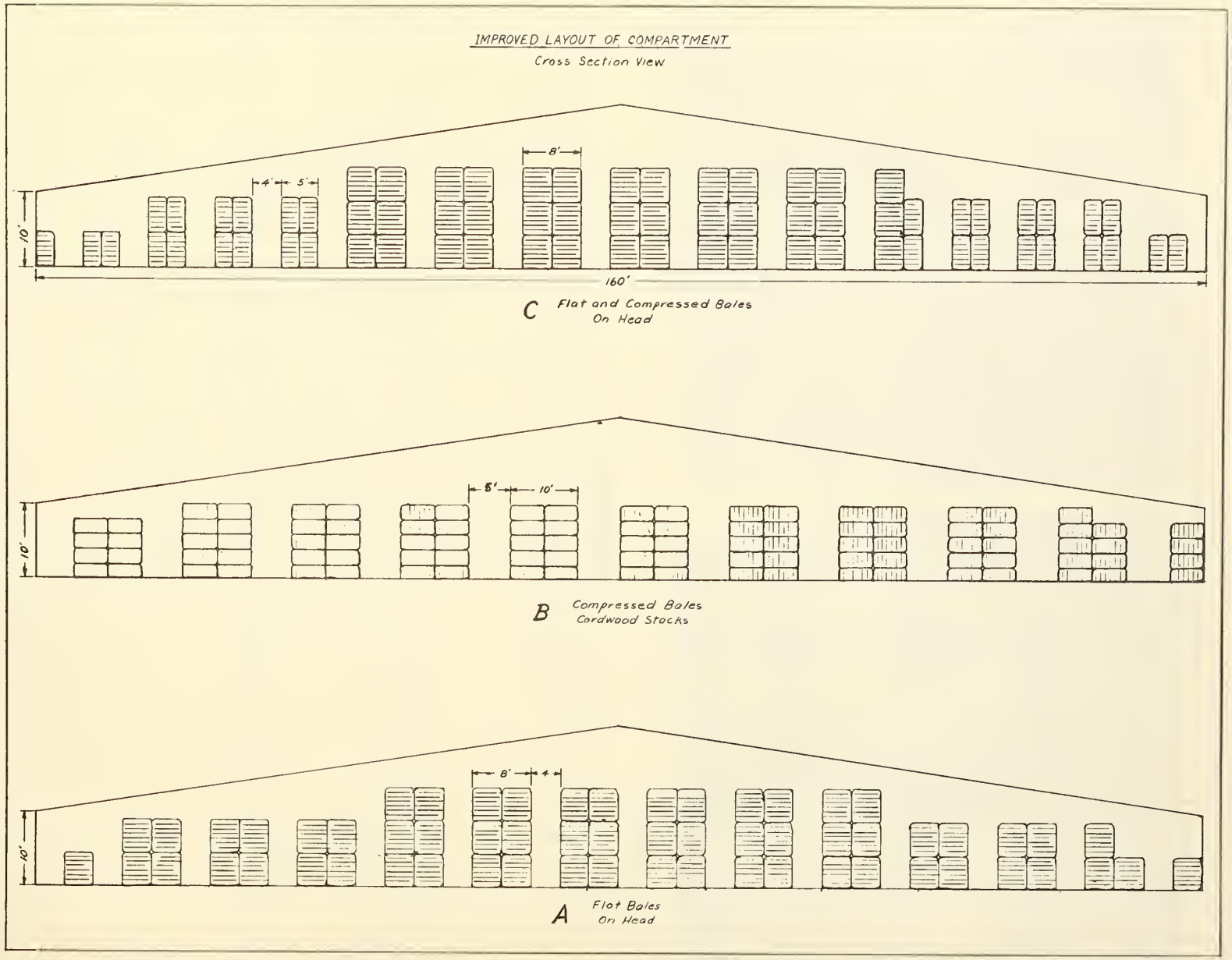
IMPROVED LAYOUT OF COMPARTMENT
Cross Section View
8'
4'
5'
10'
160'
C Flat and Compressed Bales On Head
5'
10'
10'
B Compressed Bales Cordwood Stocks
8'
4
10'
A Flat Bales On Head

Figure 5

IMPROVED LAYOUT OF COMPARTMENT
PLAN VIEW
STORAGE PATTERN FOR COMPRESSED BALES IN CORDWOOD STACKS

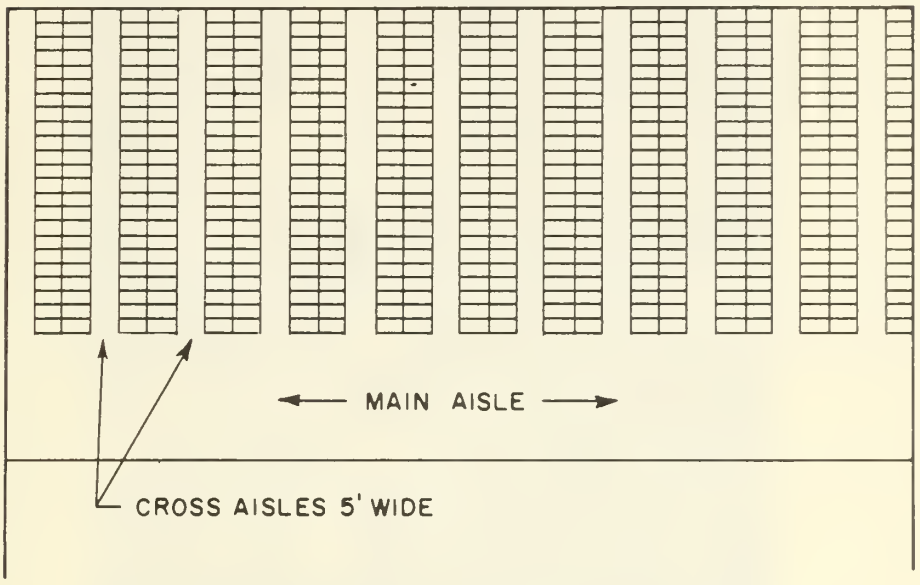

Figure 6

New Method of Storing Compressed Bales in Combination with Flat Bales

Most warehousemen prefer to store flat bales and compress them at time of shipment to standard or high density, as required. Obtaining the maximum bale storage in each compartment, however, is also desirable. If the warehouseman stores compressed bales in cordwood stacks, the capacity is increased but handling costs go up.

Experiments were made with storing compressed bales on head 1 and 2 high, and breaking them out of storage with the same device used to break out flat bales. The compressed bales are stored with the narrow side (24-inch side) of the bale facing the cross aisle, so that the bales may easily be picked up with the breakout device (fig. 7).

About half as much labor is required to place compressed bales in storage 1 and 2 high on head as in cordwood stacks (see table 1 in section "Handling Operations").

An even more significant reduction in both labor and equipment requirements occurs in the breakout operation. Breaking out compressed bales from on head stacks requires only one man and a lift truck equipped with a breakout device; 100 bales can be broken out, transported 30 feet, and set down in the main aisle in about 1½ hours. Breaking out 100 compressed bales from cordwood stacks requires about 2½ hours using three men, a lift truck with an extractor attachment, and a lift truck with 44-inch extended clamps.

BN 21804

Figure 7.--Breaking out compressed bales of cotton stored on head with the same breakout device used for flat bales.

To provide for both economical handling operations and maximum storage capacity, the new method of storing compressed bales is combined with storing flat bales in the improved layout. Flat bales can be stored 3 high on head in the highest part of the compartment, and compressed bales 1 and 2 high on head toward the sides of the compartment. As many as 7,200 bales can be stored in this compartment, about half flat and half compressed bales, if the post spacing is suitable.

The bales are stored in double rows, with 4-foot-wide cross aisles between the double rows. Compressed bales are stored 1 high in 5 rows and 2 high in 13 rows; flat bales are stored 3 high in 13 rows (figs. 5C and 8). In the end areas, rows of compressed bales are 29 bales long, and rows of flat bales are 23 bales long. These numbers double in the center area.

HANDLING OPERATIONS

The most significant improvement in handling operations in the improved layout can be seen in the storage method just discussed in which compressed bales are stored on head rather than in cordwood stacks. But handling requirements and costs for storing flat bales only or compressed bales in cordwood stacks are also lower in the improved layout than in the old because the average transport distance is shorter.

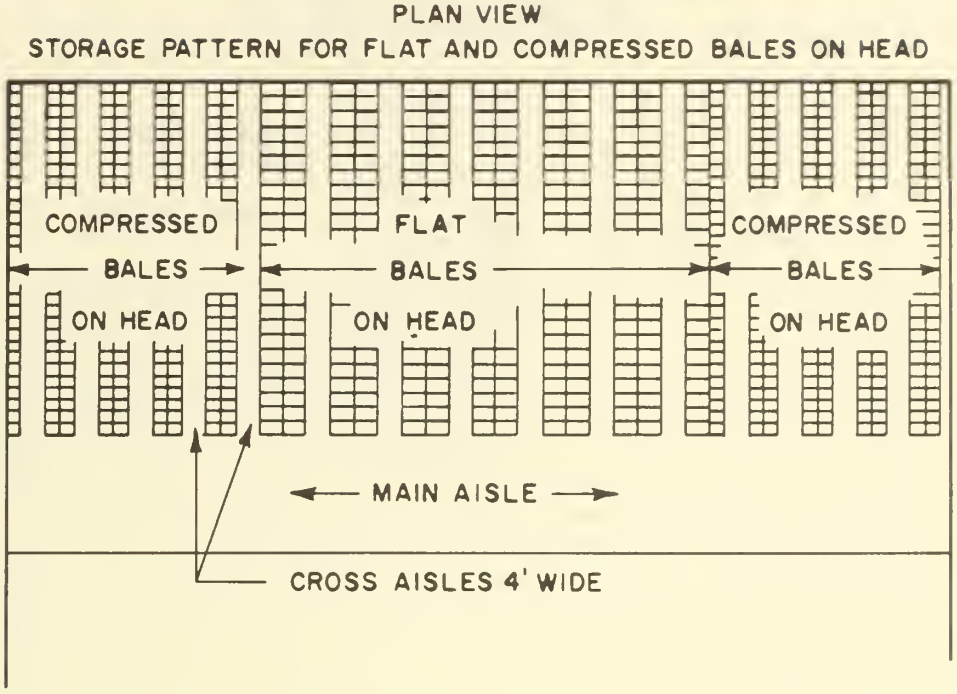

Figure 8

Figures 9 and 10 show the average transport distances involved in storing bales in the old and improved layouts. For placing flat bales in storage, the average distance is 200 feet in the old layout and 150 feet in the improved layout (from the temporary block outside of compartment to the storage row). For all other handling operations within the compartment, the average transport distance is 40 feet in the old layout and 30 feet in the improved layout. Compressed bales are usually placed in temporary blocks in the main aisle, rather than outside of the compartment, when they are ready for storage (either on head or in cordwood stacks), and the breakout operation for both flat and compressed bales involves moving them only from the storage row to a temporary block in the main aisle.

The labor requirements and elapsed time for storing and breaking out flat and compressed bales in the old and improved layouts are given in table 1. Except for breaking out compressed bales from cordwood stacks, each handling operation requires one worker.

Equipment requirements depend on the number of bales handled per season. Except for storing and breaking out compressed bales from cordwood stacks, it is assumed in this report that each storage method requires two 3,000-pound lift trucks: One equipped with 3-bale clamps for storing bales and one equipped with a device for breaking out bales. For warehousemen handling fewer than 7,500 bales per season, one 3,000-pound lift truck may be adequate for both the storing and breaking out operations. Clamps and breakout devices are interchangeable on the face plate of the lift truck. Equipment necessary for handling compressed bales in cordwood stacks consists of three 3,000-pound lift trucks: One equipped with 3-bale clamps, one equipped with an extractor,

OLD LAYOUT OF COMPARTMENT
Transport Distances

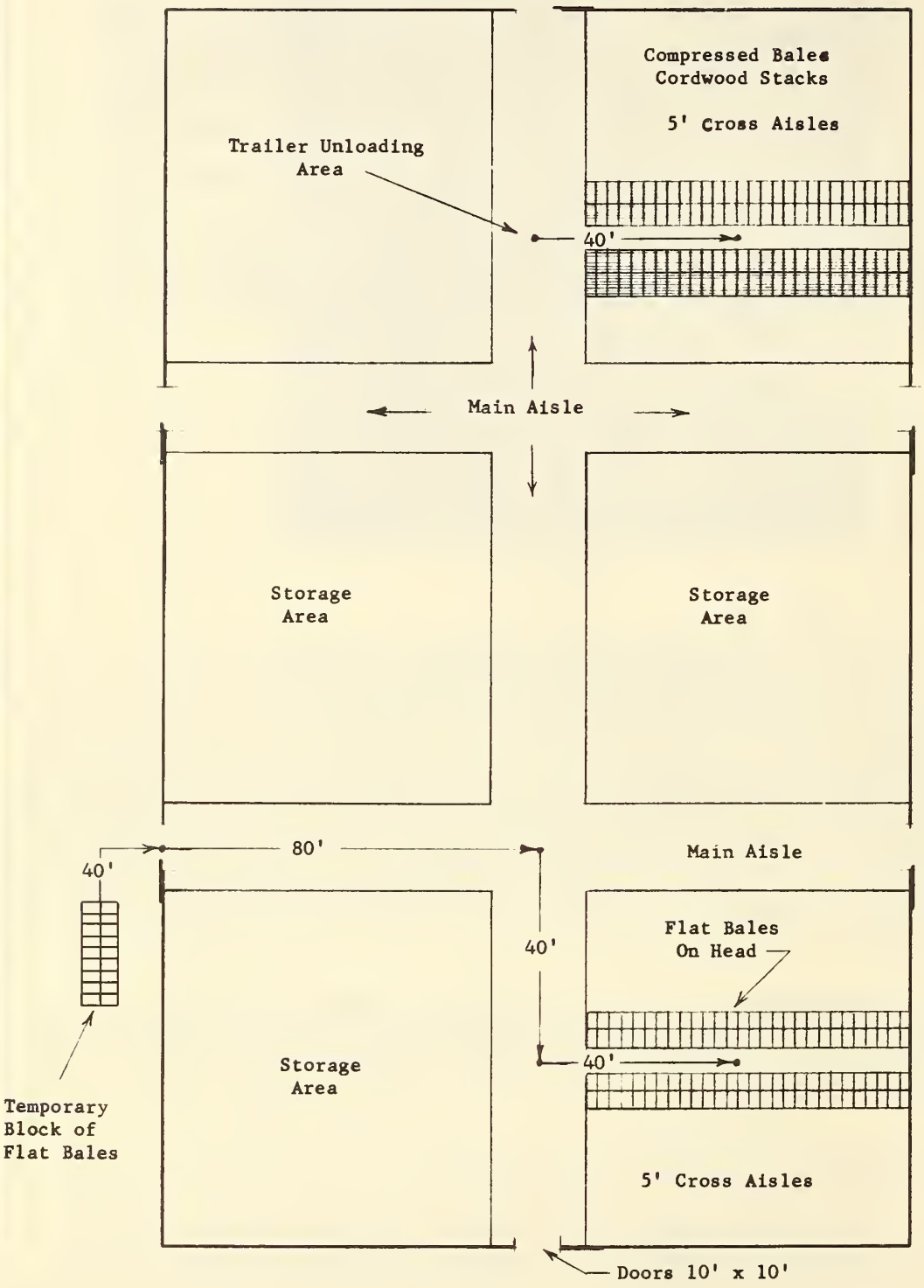

Figure 9

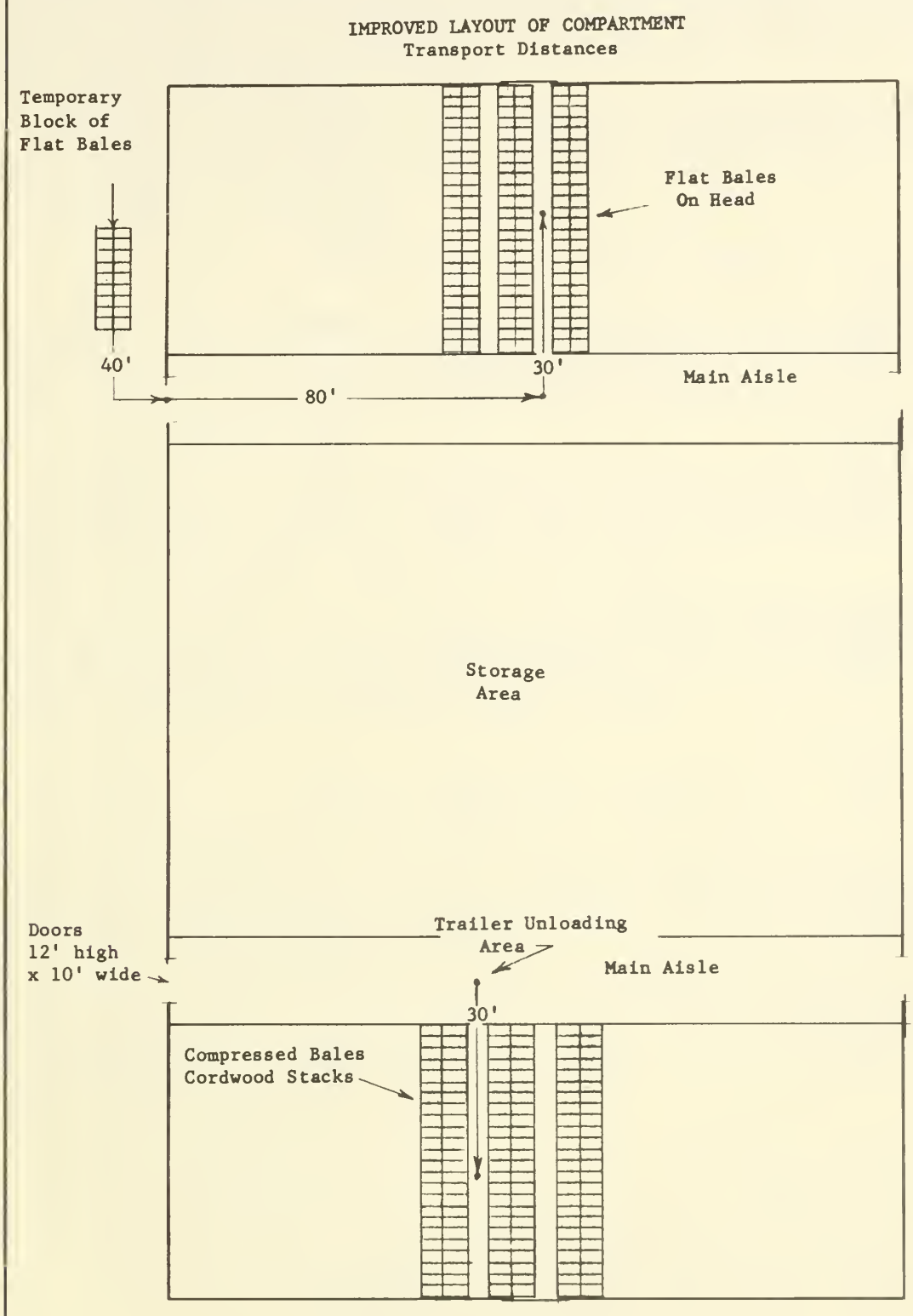
IMPROVED LAYOUT OF COMPARTMENT
Transport Distances
Temporary
Block of
Flat Bales
Flat Bales
On Head
40'
30'
Main Aisle
80'
Storage
Area
Doors
12' high
x 10' wide
Trailer Unloading
Area
Main Aisle
30'
Compressed Bales
Cordwood Stacks

Figure 10

Table 1.--Labor requirements per 100 bales for storing and breaking out flat and compressed bales of cotton, old and improved layouts 1/

Bale, storage method, and operation	Labor required 2/	
	Old layout	Improved layout
	Man-hours	Man-hours
FLAT BALES, on head:		
Storing:		
1 high	0.57	0.50
2 high	.63	.56
3 high	.69	.62
Breaking out:		
1 high	1.24	1.14
2 high	1.37	1.27
3 high	1.51	1.41
COMPRESSED BALES, on head:		
Storing:		
1 high	--	.32
2 high	--	.38
Breaking out:		
1 high	--	1.21
2 high	--	1.41
COMPRESSED BALES, cordwood stacks:		
Storing:		
4 high	.65	.61
5 high	.67	.63
Breaking out:		
4 high	3/ 4.34	4/ 4.32
5 high	5/ 4.60	6/ 4.58

1/ The elapsed time for the operation is the same as the labor required unless otherwise noted.

2/ Labor requirements for each operation are based on the work elements described in tables 5 and 6 in the appendix.

3/ The elapsed time for the operation is 2.49 hours.

4/ The elapsed time for the operation is 2.47 hours.

5/ The elapsed time for the operation is 2.62 hours.

6/ The elapsed time for the operation is 2.60 hours.

and one equipped with 44-inch extended clamps. In warehouses where fewer than 7,500 compressed bales are handled, one 3,000-pound lift truck is adequate for both storing and breakout operations.

Labor and equipment costs for storing and breaking out flat and compressed bales in three stacking patterns, in the old and improved layouts, are given in tables 2 and 3.

ADVANTAGES OF THE IMPROVED LAYOUT

The principles of layout illustrated in this report may be used to advantage in rectangular warehouse compartments of various sizes and with various post spacings. The warehouseman can figure for himself the amount of storage space he can gain by running the main aisle or aisles the width of the compartment rather than the length.

In addition to the increased income to be expected from the greater capacity for storing bales, unit handling costs for storing and breaking out bales should be reduced. The amount of reduction depends on the method of storage now used, and the method chosen for the improved layout.

Table 4 compares storage capacity and handling costs for the old and improved layouts in one storage compartment of the size described in this report. Average cost per hundred bales handled should be less for all three storage patterns when the improved layout is used.

MODIFYING THE STORAGE COMPARTMENT

Adoption of the improved layout can be accomplished by relocating doors in sidewalls and, if necessary, building a 20-foot roadway along one side of the compartment to provide access to the new doors. Relocation of two sliding doors would cost around $100 and asphalt paving, meeting highway specifications, for 20-foot roadways should cost $1.35 to $1.85 per square yard, depending on the locality. New lines should be painted on the compartment floor to indicate the new storage rows. It is recommended that the warehouseman consult a local architect, engineer, or builder regarding the strength of floors and structural members necessary to support wheel loads exerted by 3,000-pound lift trucks, if he is not now using trucks of this capacity.

Table 2.--Flat bales: Labor and equipment costs to store and break out 100 bales on head, 1, 2, and 3 high in old and improved layouts

Operation, layout, and stacking height	Crew size	Elapsed time	Costs		
			Labor 1/	Equipment 2/	Total
	Workers	Hours	Dollars	Dollars	Dollars
Storing:					
Improved layout:					
1 high	1	0.50	0.63	0.89	1.52
2 high	1	.56	.76	1.00	1.76
3 high	1	.62	.84	1.10	1.94
Old layout:					
1 high	1	.57	.77	1.01	1.78
2 high	1	.63	.85	1.12	1.97
3 high	1	.69	.93	1.23	2.16
Breaking out:					
Improved layout:					
1 high	1	1.14	1.54	2.03	3.57
2 high	1	1.27	1.71	2.36	3.97
3 high	1	1.41	1.90	2.51	4.41
Old layout:					
1 high	1	1.24	1.67	2.21	3.88
2 high	1	1.37	1.85	2.44	4.29
3 high	1	1.51	2.04	2.69	4.73

1/ Based on assumed wage rates and labor requirements described in the appendix.

2/ Based on table 7 in the appendix.

Table 3.--Compressed bales: Labor and equipment costs to store and break out 100 bales in 4 and 5 high cordwood stacks and 1 and 2 high on head stacks in old and improved layouts

Operation, layout, and stacking height	Crew size	Elapsed time	Costs		
			Labor 1/	Equipment 2/	Total
	Workers	Hours	Dollars	Dollars	Dollars
Storing:					
Improved layout:					
Cordwood stacks:					
4 high	1	0.01	0.82	1.09	1.91
5 high	1	.63	.85	1.12	1.97
On head stacks:					
1 high	1	.32	.43	.57	1.00
2 high	1	.38	.51	.66	1.17
Old layout:					
Cordwood stacks:					
4 high	1	.65	.88	1.16	2.04
5 high	1	.67	.90	1.19	2.09
Breaking out:					
Improved layout:					
Cordwood stacks:					
4 high	3	2.47	5.66	4.39	10.03
5 high	3	2.60	5.98	4.62	10.60
On head stacks:					
1 high	1	1.21	1.63	2.15	3.78
2 high	1	1.41	1.90	2.51	4.41
Old layout:					
Cordwood stacks:					
4 high	3	2.49	5.67	4.43	10.10
5 high	3	2.62	6.01	4.66	10.67

1/ Based on assumed wage rates and labor requirements described in the appendix.

2/ Based on table 7 in the appendix.

Table 4.--Total storage capacity and cost of handling bales of cotton in compartments, old and improved layouts

Type of bale and layout	Storage capacity of compartment	Handling cost: Storing: Labor	Storing: Equipment	Storing: Total	Breakout: Labor	Breakout: Equipment	Breakout: Total	Total cost	Average cost per 100 bales
	Bales	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Flat bales:									
Improved layout.....	5,600	45.56	59.77	105.33	102.90	135.93	238.83	344.16	6.11
Old layout	4,500	40.34	53.26	93.60	88.19	115.34	203.53	297.13	6.60
Compressed bales:									
Improved layout.....	9,300	79.37	104.75	184.12	555.64	430.53	986.17	1,170.29	12.58
Old layout..	8,700	78.63	103.91	182.54	521.27	404.81	926.08	1,108.62	12.74
Flat and compressed bales combined, improved layout	7,200	48.34	63.12	111.46	135.66	179.21	314.87	426.33	5.91

APPENDIX

Labor Requirements

Data from Marketing Research Report No. 250, "Handling Bales of Cotton in Public Warehouses," in addition to experiments and time studies reported here were used to determine the stacking and breakout operations to be performed, and the man-hour requirements per 100 bales (tables 5 and 6).

Costs

Computations of handling costs in this report include only the direct labor and equipment costs for storing and breaking out bales of cotton. Management, warehouse maintenance, overhead, and facility costs are not included, and the cost data therefore do not reflect total costs to the warehouseman.

Labor costs are based on the productive time required to perform the operation and on the following assumed wage rates: $1.25 per hour for the worker who helps break out compressed bales from cordwood stacks and $1.35 per hour for all other workers. Wage rates in many areas differ from these assumed rates. Warehousemen can substitute the rates that apply to their own situations. No allowances were made in these assumed wage rates for such additional but indirect labor costs as pay for vacations and holidays, employers' contributions for old age and unemployment compensation, employees' insurance for life and health, or other fringe benefits.

Equipment costs are computed on the basis of ownership costs, which are considered to be relatively constant from year to year, and operating costs, which are variable, as they directly reflect the hours of use of the equipment. It is assumed, for the purpose of this report, that the equipment is used for 1,000 hours annually.

Ownership costs consist of depreciation, interest, taxes, and insurance. Operating costs include fuel, oil, servicing, repair, maintenance, overhauling, and inspection.

Table 7 shows the estimated ownership and operating costs of the equipment used in the improved and old layouts described in this report. In warehouses where a specified type of equipment is actually used more than the annual hours of use assumed here, average hourly costs are probably lower. Conversely, average hourly costs are probably higher in warehouses in which the actual hours of use are less.

Table 5.--Flat bales: Productive labor required for one man to store and break out 100 bales, 1, 2, and 3 high on head

Time item	Productive labor
	Man-hours
Storing bales: 1/	
Pick up bales	0.07
Move bales to storage stack:	
150 feet (improved layout)	.38
200 feet (old layout)	.45
Set bales down in stacks:	
1 high	.05
2 high	.11
3 high	.17
Breaking out bales: 2/	
Break out bales from stacks:	
1 high	.47
2 high	.60
3 high	.74
Move bales to temporary block in main aisle:	
30 feet (improved layout)	.52
40 feet (old layout)	.62
Set bales down in block	.15

1/ One man using a 3-bale clamp truck handles 3 bales at a time.
2/ One man using a clamp truck with breakout device handles 1 bale at a time.

Table 6.--Compressed bales: Productive labor required to store and break out 100 bales 1 and 2 high on head and 4 and 5 high in cordwood stacks

Time item	Crew size	Productive labor
	Men	Man-hours
Storing bales on head 1/	1	--
Pick up bales	--	0.09
Move bales 30 feet	--	.17
Stack bales:		
1 high	--	.06
2 high	--	.12
Storing bales in cordwood stacks 1/	1	--
Pick up bales standing on head and position horizontally	--	.22
Move bales:		
30 feet (improved layout)	--	.17
40 feet (old layout)	--	.21
Stack bales:		
4 high	--	.22
5 high	--	.24
Break out bales from on head stacks 2/	1	--
Break out bale from stacks:		
1 high	--	.54
2 high	--	.74
Move bales 30 feet to main aisle	--	.52
Set bales down	--	.15
Break out bales from cordwood stacks: 3/		
Break out bales and set down in cross aisle	2	--
Break out bales from stacks:		
4 high	--	3.26
5 high	--	3.52
Set bales on head in cross aisle	--	.44
Move bales from cross to main aisle	1	--
Pick up bales in cross aisle	--	.28
Move bales to main aisle:		
30 feet (improved layout)	--	.26
40 feet (old layout)	--	.28
Set bales down	--	.08

1/ One man using a 3-bale clamp truck handles 3 bales at a time.
2/ One man using a clamp truck with breakout device handles 1 bale at a time.
3/ Two men using a clamp truck equipped with an extractor break out bales 1 at a time and set them down on head in the cross aisle, and 1 man using a 2-bale clamp truck with 44-inch extended clamps moves 2 bales at a time to the main aisle.

Table 7.--Estimated costs of ownership and operation of specified types of materials-handling equipment in cotton compresses and warehouses, based on 1,000 hours of annual use and depreciation in 8 years

Type of equipment	Initial cost 1/	Cost of ownership 2/		Cost of operation per hour 3/	Total cost per hour
		Per year	Per hour		
3,000-pound lift truck equipped with:					
3-bale clamp.....	$6,500	$1,105	$1.11	$0.67	$1.78
2-bale, 44-inch extended clamp arms.....	6,500	1,105	1.11	.67	1.78
Breakout device for flat bales.....	6,500	1,105	1.11	.67	1.78
Extractor for compressed bales.....	6,800	1,156	1.16	.61	1.77

1/ Equipment cost does not include freight or tax charges.

2/ Allowance for insurance and taxes, 2 percent; allowance on investment, 5 percent on average investment.

3/ Average costs, gasoline 25¢ per gallon, oil 25¢ per quart; cost of maintenance and parts obtained from various-sized warehouses and compresses.

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